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Virtual Windtunnel Project Plan

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abstract

This report contains the initial project plan for the *virtual windtunnel* project. The virtual windtunnel is an environment for the interactive visualization of three dimensional unsteady flows, using the technology of "virtual reality". This report has three parts. Part one is a description of the project elements. Part two consists schedules. Part three is the proposed budget for the first year of the project,

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Virtual Windtunnel: FY91 Project Plan

I. Goals

The virtual windtunnel project has three main goals: The first goal is to construct a virtual environment for the exploration of three dimensional unsteady flow solutions (see ref. [1]). The second goal is to evaluate the applicability of virtual reality (VR) technology to the NAS mission, specifically to the task of 3D unsteady flow visualization. The third goal is to contribute to the Ames-wide collaborative effort on VR technology research and development.

II. Deliverables

At the end of the first year, a prototype system for the interactive visualization of 3D unsteady flows in a virtual environment will be ready for demonstrations. Several visualization techniques will be supported. Three dimensional unsteady flows defined numerically on single, static, curvilinear, topologically regular grids will be supported in the demonstration system. A color stereo head-position-sensitive display of the highest feasible resolution will be incorporated. Hand-position-sensitive interactions will be emphasized (i.e. emitting "smoke" into the flowfield from your index finger).

Also at the end of the first year, a set of brief reports written in collaboration with code FLM (where most of the VR technology was initially developed) will be finished. These reports will deal with issues such as the relative importance of resolution, tracker distortion, frame rates, lag times, etc. on the performance of simple tasks (such as particle placement) in a virtual environment.

Finally, an evaluation by the virtual windtunnel team, NAS management, and virtual windtunnel users will be performed. If agreement can be reached, then a second phase of the project will begin. This second phase will consist of several enhancements, including an upgrade to a shared environment (where two users can simultaneously and mutually explore the same flow), upgrades to include new types of 3D data management in virtual space, voice input/output, support of larger, more complicated engineering datasets, and integration with other flow visualization tools. The result of this second phase will be virtual windtunnel IOC, a fully operational engineering tool.

III. Details Of Phase I Plan

The the attached schedule (figure 1) for a brief list of the phase I (FY91) components of the project. See attached budget (table 1) for the proposed FY91 budget. The booms, gloves, and other user accessible parts of the virtual windtunnel will be located in the NAS virtual reality laboratory, in room 117 of building T-045. The iris 380 VGX, scan converters, and some other machinery will be located in room 119 (the machine room) of building T-045.

III.A. Hardware components

III.A.0 Monochrome boom. (not listed on accompanying schedule).

At present, the monochrome boom is complete and in use. A few minor enhancements like new grips, a video sync combiner, and some buttons will be added.

III.A.1 IRIS 380 VGX.

The computational and rendering engine for the virtual windtunnel will be a Silicon Graphics iris 380 VGX. It will be configured with 256 MBytes of RAM. This is the minimum that will allow us to keep an interesting 3D unsteady flowfield in memory. (for an overview of the computational, memory, and graphics requirements for the virtual windtunnel, see ref. [1]) This machine has eight processors and approximately 20 MFLOPS sustained performance. Such performance is necessary to advect a large number of particles at an acceptable frame rate while simultaneously running the additional tasks necessary to track the hand, track the head, and manage the rendering.

The 380 VGX will be obtained by upgrading an existing 340 VGX belonging to the applied research branch. (see accompanying FY 91 budget).

III.A.2 Color Boom.

A color version of the boom mounted display already in use by the applied research branch will be constructed. It will contain color CRTs of the highest feasible resolution, subject to cost, weight, and safety constraints.

III.A.2.a Study.

Two studies will be undertaken (by Fake Space labs under subcontract to CSC). The first will survey the market for specifications and availability of candidate CRTs for the color boom. Size, weight, resolution, electronics, voltage, electromagnetic emissions, and price data will be gathered and evaluated. One or more candidate CRTs will be selected. The second study will focus on the safety issue. How safe is it to have color CRTs one inch from your eyes, and for how long. In particular, the candidate CRTs will be evaluated for safety from the point of view of boom use. The safety issues of CRT emissions of x-ray, ultraviolet, visible, infrared, radio, and extremely low-frequencies will be surveyed, and emphasis will be placed on the selected candidate CRTs.

III.A.2.b Design.

A color boom will be designed by Fake Space Labs. It will incorporate the results of the studies detailed above to, if necessary, shield the CRTs or move them farther from the user's eyes. It may require some custom electronics to drive the CRTs. It will incorporate the new extremely wide field optics from pop-optix labs.

III.A.2.c Install.

The color boom will be installed and integrated into the existing virtual windtunnel environment at NAS.

III.A.2.d VGX stereo.

In order to use the color boom, a separate color image must be rendered for each eye. To use a single VGX machine for this requires some additional hardware. The multi-display adapter board from SGI, along with two additional color scan converters, will be needed. A small video rack to hold the two scan converters and two auxiliary monitors will also be constructed.

III.A.3 Headmount.

A headmounted stereo LCD display will be integrated into the system as an alternative to the color boom, at least for comparison purposes. The new extremely wide field-of-view enhanced resolution color LCD headmount from pop-optix labs is the probable candidate.

III.A.4 Monocular.

In collaboration with code FLM, we will evaluate the applicability of a dual resolution display system. This monocular prototype display from pop-optix labs has a high-resolution narrow (30 degree) central field and a low resolution wide field surrounding it. It is a candidate for future placement in head-mounted or boom-mounted displays. (see also III.C below)

III.B Software Development

III.B.1 Steady flow prototype.

This is presently complete and being demonstrated (see ref. [3]). Some minor enhancements will we added, such as polygon display of grid surfaces and and better inverse interpolation of hand position.

III.B.2 Unsteady flow prototype.

The unsteady flow prototype is a complete rewrite of the steady flow prototype to allow the visualization of three dimensional unsteady flowfields using a variety of "windtunnel-like" techniques, described below.

Initial prototypes of unsteady flow visualization on the connection machine (see ref. [2]) indicate that for a time accurate solution running at a CFL number of about 24, saving every tenth step is adequate for visualization via particle advection. Therefore, the prototype virtual windtunnel, with 256 MBytes, should allow visualization of periodic flows on medium size grids (20 timesteps on a one million point grid), or of nonperiodic flows on small grids (160 steps on a 128K point grid).

For details on the computer system requirements for this project, and some speculations about where it may lead, see reference [1].

III.B.2.a Particle paths.

From an initial point specified by the user's hand, the path of an infinitesimal fluid element ("particle") is integrated through the unsteady velocity field and its path over time is displayed, akin to a time exposure. Additional particles released from the same point in space at other times will, in general, follow other paths.

III.B.2.b Dye advection.

Collections of particles ("patches" or "blobs") of various sizes and colors can be placed into the flowfield, and their positions updated, based on the changing velocity field, as virtual time advances.

III.B.2.c Streaklines (bubbles).

From a particular point in space, particles are continuously emitted, one per timestep. Their positions are all updated, based on the changing velocity field, and displayed at every succeeding timestep.

III.B.2.d Streamlines.

From a particular point in space and time, an integral curve through the instantaneous velocity field is computed and displayed. This curve will, in general, change at every timestep.

III.B.2.e Tufts.

The user can place small markers, indicating the local instantaneous velocity, at various points in the flowfield.

IIIB.2.f Navigation.

The user will be able to change her position and orientation, her scale, and the position and orientation of the data. This is in addition to the position and orientation information provided by the boom-mounted or head-mounted display.

III.B.2.g Time control.

The ability to stop (virtual) time, change the rate of flow of time, run time backwards, and loop over a particular subinterval of time will be supported.

III.B.2.h Object control.

Adding, moving, and deleting streamline seedpoints, dye blobs, tufts, etc, will be supported. Ability to Group and ungroup these objects into "rakes" and move these rakes around will also be implemented.

III.B.2.i Rendering control.

Various paths (particle paths, streamlines, etc.) can be rendered as points or lines. Their color may vary based on position, age, or type. Geometry information (grid surfaces) can be rendered using lines or shaded polygons. Lights may be positioned and oriented based upon the users hand.

III.B.2.j Initial demonstration.

The system described above will be demonstrated and evaluated. If agreement is reached, a second phase of the project will be undertaken.

III.C RNR - FLM collaboration (not shown on schedule)

Several research projects and experiments will be carried out by code FLM with cooperation, planning, participation, and support (one FTE equivalent, a small hardware budget) from RNR. The details of this collaboration are currently being agreed upon.

The probable nature of this collaboration will be a series of studies and experiments performed by FLM. For example, the relative importance of tracker distortion, frame rate, lag time, and resolution in a virtual environment with respect to tasks such as pointing, placing, "grabbing" and navigation may be studied. Generic, portable software for handling these tasks in a virtual environment may be developed. The implications of optical distortion introduced by the wide field optics, and possible solution methods to this problem is another possibility. (see also III.A.4 above)

IV. Virtual Windtunnel Phase II

Phase two will extend and enhance the capabilities of the virtual windtunnel in several key areas, culminating in a fully operational system for use by any NAS user. The extensions of functionality will be in the areas of supporting new visualization techniques (virtual data probes), supporting shared exploration of a flowfield (shared virtual environments), support for complex engineering datasets (multi-zone grids, multiple fields), distributed programming (to support the shared environment and to support extremely large datasets using supercomputers), new hardware (better trackers and displays), and system integration with other Ames visualization software.

See the attached schedule (figure 2) for a list of phase II (FY 1992) project elements. A detailed cost breakdown of phase II has not been developed; A first order estimate of the cost of phase two is that it will be less than or equal to the cost of phase one ($300k - $350K).

IV.A Hardware (Phase II)

IV.A.1 2nd iris VGX

A second, possibly smaller, VGX machine will be needed to implement the shared environment, including a prototype long distance share capability.

IV.A.2 Color display (phase II)

A new color display system, lighter, with higher resolution, better contrast, and wider field-of-view, will be implemented.

IV.A.3 Tracker II

A tracker more capable than the polhemous/dataglove combination will be incorporated into the system.

IV.B Software (phase II)

IV.B.1 Virtual data probes

Virtual data probes are active elements that visualize properties of the data over time and are placed in response to user input. Examples are tufts, pressure meters, and "smoke" sources.

IV.B.1.a local display

Virtual data probes with local display render their output images at a place in the virtual environment coincident with the part of the flowfield in which they are placed. A vector representing the local velocity at a point is one example. A small surface patch with pressure contours updated over time is another example.

IV.B.1.b remote display

Virtual data probes with remote display have their output rendered at a different place in the virtual environment than from the position at which they are initially placed. An example is specifying that the time history of the pressure a particular gridpoint should be rendered on a "strip chart recorder" off to the side of the grid.

IV.B.1.c 0D base

Some virtual dataprobes accept their input from a single point in the flowfield. These are said to have a zero-dimensional base.

IV.B.1.d 1D base

Virtual data probes that accept input from a curve in the flowfield (i.e. a particular grid line) are said to have a one-dimensional base.

IV.B.1.e 2D base

Probes of this type take input data from a 2 dimensional submanifold of the flowfield. An example is a grid surface (or section of one) colored by a scalar.

IV.B.1.f 3D base

A dataprobe with a 3D base has subvolume of the flowfield is its input.

IV.B.1.g rank 0 fiber

The rank of the fiber of a dataprobe refers to the dimensionality of the quantities it is measuring. A dataprobe with a rank 0 fiber measures and displays a scalar quantity.

IV.B.1.h rank 1 fiber

These dataprobes measure a vector quantity and display it.

IV.B.1.i rank 2 fiber

Tensor quantities (rank two tensor quantities, that is) are measured by these dataprobes. Higher rank data dataprobes are defined analogously.

IV.B.2 Data Realm Management

IV.B.2.a 3D layout

This is the process by which the multiple views, dataprobes, and user interfaces are arranged to fill the virtual space.

IV.B.2.b Shared Environment

Two or more users will be able to interact with the same virtual environment at the same time. The users may be different (virtual) sizes, may be in different places, and may be seeing different views of the data. They may also be in different cities.

IV.B.2.c Voice I/O

Voice input as part of the user interface will be supported

IV.B.2.d Non-VR integration

The virtual windtunnel will be integrated with other Ames visualization software.

IV.C IOC

At this point, the virtual windtunnel will be fully operational and available to the NAS user community.

V References

[1] C. Levit. *The Virtual Windtunnel: An Environment for the Interactive Visualization of Three Dimensional Unsteady Flows.* Report RNR-90-015. NASA Ames Research Center.

[2] D. Jespersen and C Levit. *Numerical Computation of Flow Past a Tapered Cylinder.* AIAA 29th aerosciences meeting. Reno, NV. 1991.

[3] S. Bryson and C. Levit. *A Virtual Environment for the Exploration of Three-Dimensional Steady Flows.* Report RNR-90-013. NASA Ames Research Center, 1990.

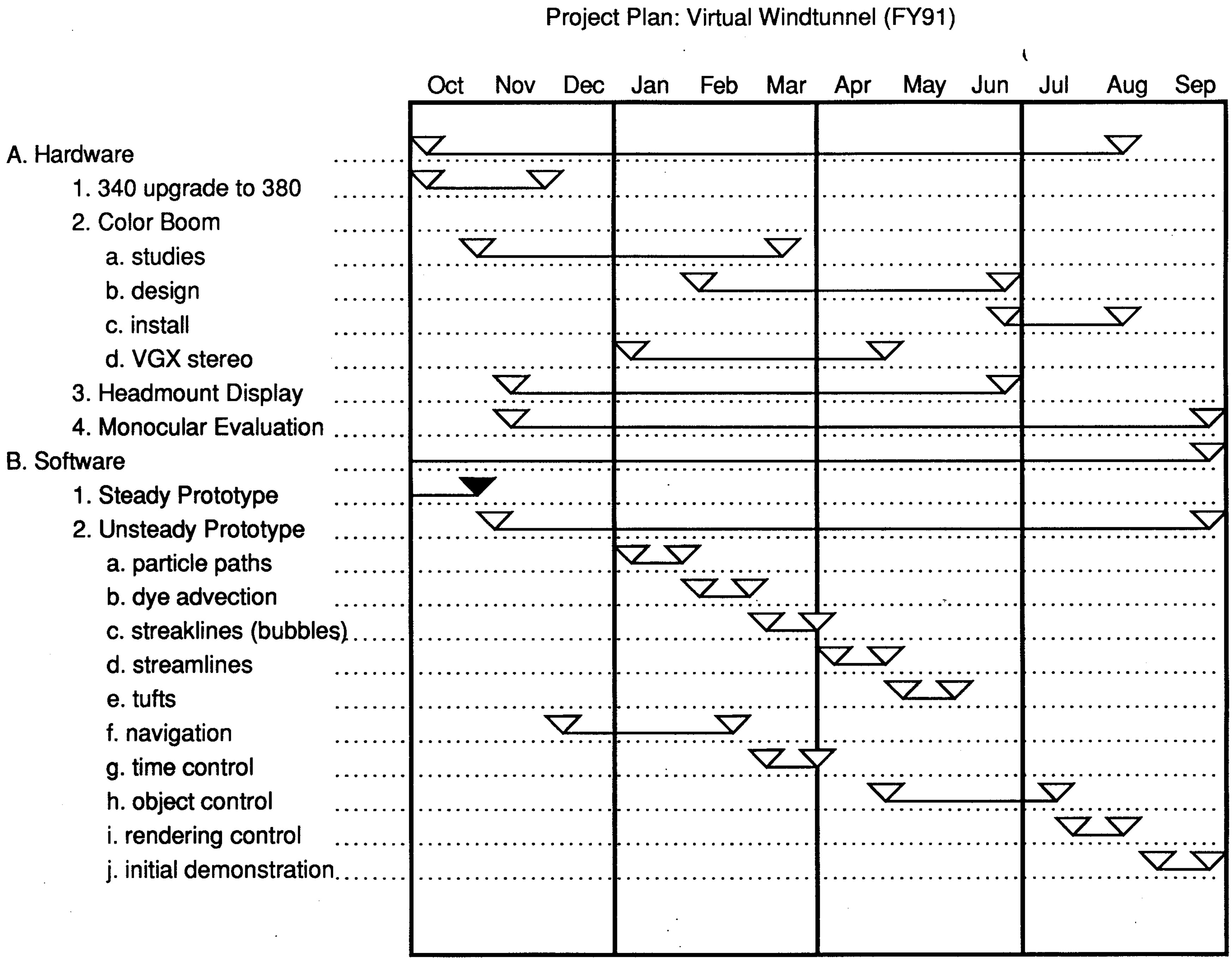

Figure 1: Virtual Windtunnel Phase I Schedule

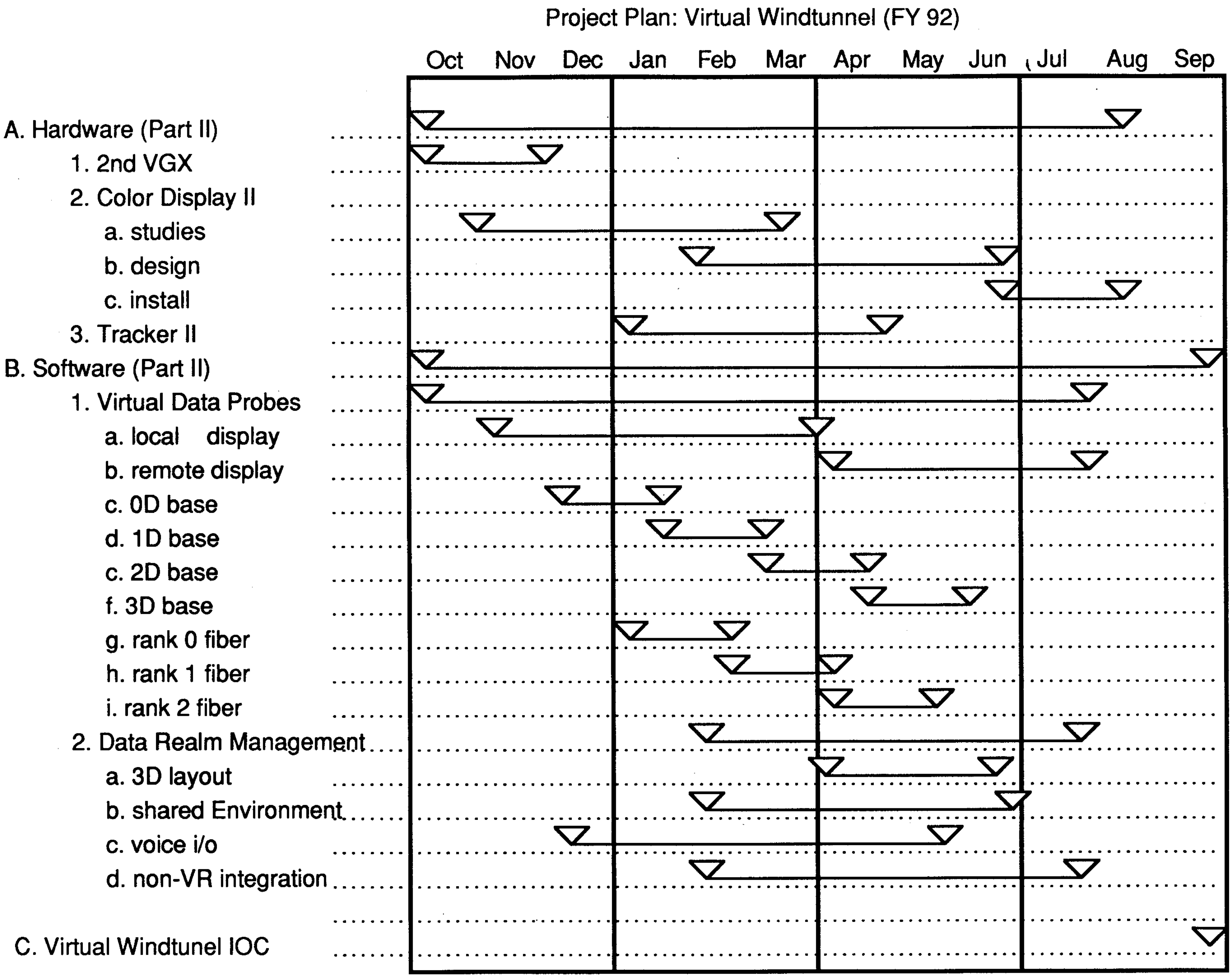

Figure 2: Virtual Windtunnel Phase II Schedule

Virtual Windtunnel: FY91 Budget Requirements

A.0	Monochrome boom upgrades:		10,000
A.1	SGI Iris 380 VGX		
	Iris 340 VGX (existing WK2)	0	
	rack chassis upgrade	15,730	
	two 320 → 340 upgrades	57,200	
	48MByte → 256 MByte upgrade	70,000	
	total:		142,930
A.2	Color Boom		
	CRT and LCD display study	5,000	
	preliminary design	5,000	
	safety study	5,000	
	Color CRTs	15,000	
	Electronics	10,000	
	Mechanical	25,000	
	total:		65,000
A.2d	VGX stereo		
	two scan converters	30,000	
	stereo board	3,000	
	splitter (120 hz to 2 x 60 hz)	5,000	
	total:		38,000
A.3	Headmounted display		
	display system:	9,000	
	second dataglove	8,000	
	total:		17,000
A.4	Monocular		
	display system:	10,000	
	FLM collaboration (1 FTE)	80,000	
	total:		90,000
total:			326,930

Table 1: Virtual Windtunnel FY91 Budget